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ACCURACY OF INFORMATION ASSIMILATION FROM UPDATED ALPHA-NUMERIC--ETC(U)
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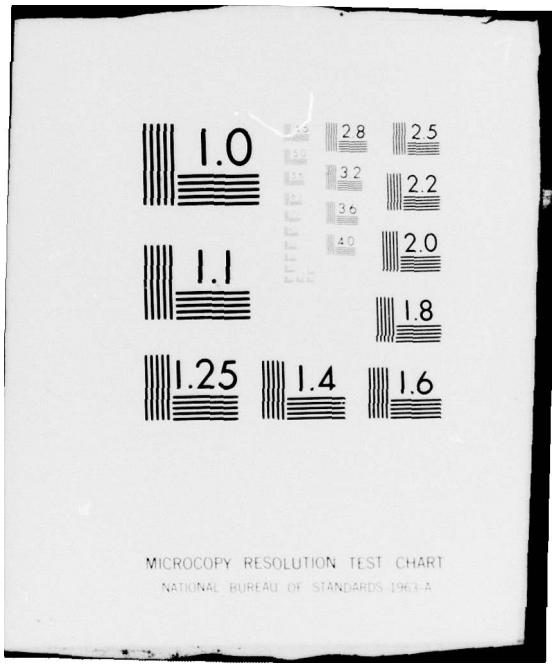
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Research Memorandum 65-5

ACCURACY OF INFORMATION ASSIMILATION FROM UPDATED ALPHA-NUMERIC DISPLAYS

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(10) by C. H. Hammer

Seymour Ringel, Task Leader

(12) 23

Submitted by:
Joseph Zeidner
Chief, Combat Systems
Research Laboratory

Approved by:
J. E. Uhlaner
Director of
Laboratories

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ACCURACY OF INFORMATION ASSIMILATION FROM UPDATED ALPHA-NUMERIC DISPLAYS

In command information processing systems being considered for development, military information will be presented to commanders and their staffs to aid in the making of tactical decisions. As a preliminary to the decision process, information must be rapidly and accurately assimilated from displays. In particular, information which has been updated because of changes in the military situation may need to be immediately apprehended.

The Command Systems Task of the U. S. Army Personnel Research Office has initiated a series of studies designed to provide information on the optimization of human performance in command information processing systems. Studies have been concerned with the assimilation of alpha-numeric information from charts and the assimilation of symbolic information from maps and overlays.

In a recently completed study on the assimilation of alpha-numeric information (Hammer and Ringel, 1964), subjects were required to locate updated information by comparing updated charts with hard copy "history". The updates were size coded in half the charts presented and uncoded in the remaining half. While amount of time taken to locate updates was the principal dependent variable, the study yielded the following findings concerning errors: (1) Two types of error were found, errors of omission and errors of commission (in the ratio of three to one). (2) Errors were reduced by half when coded updates were used. The low frequency of errors, however, precluded a more detailed analysis of the data. It was felt that a more stressful experimental task might yield more information on how accuracy and error scores are affected by coding, amount of information presented, and amount of information updated. Accordingly, the present experiment was designed to provide this information. An additional purpose was to determine if the effects of the independent variables on errors were similar to those found in a study on the assimilation of symbolic information (Ringel and Vicino, 1964).

METHOD OF INVESTIGATION

STIMULUS MATERIALS

The conspicuity technique used in this experiment--as in the previous alpha-numeric study (Hammer and Ringel, 1964)--was size coding, which appeared to be feasible in terms of system hardware capability.

Charts used in the experiment were adapted in format and content from charts contemplated for use in an automated information processing system. They were the same charts as were used in the previous study. All stimulus charts contained six columns of information: three columns of words and three columns of numbers with random assignment of information within each column. Each chart was divided into blocks of equal size, and random assignment of updates was made to the cells or cell within each block. This procedure prevented the chance assignment of all updates to a restricted area of a given chart, and thereby reduced effects of position of updates on performance. All uncoded information was typed into the charts; the coded information, prepared by "Headliner", was pasted into the appropriate cells. All charts were then reproduced as 35 mm negative slides. Figure 1 is an example of a coded stimulus chart with a total of 90 elements, of which 16 are updated coded elements. For each coded stimulus chart there was an uncoded stimulus chart identical in content. Figure 2 shows a hard copy "history" answer chart corresponding to the stimulus chart in Figure 1. All answer charts were uncoded.

APPARATUS

The experiment was conducted in a light-proofed room equipped with rheostatically controlled overhead indirect light fixtures. The 35 mm slides were rear-projected to provide charts 59" wide and 46" high. The height and stroke width of letters or numbers on the screen was 7/8" and 1/8", respectively, for uncoded characters and 1-3/16" and 1/4", respectively, for coded characters. The average luminance value of letters and numbers was approximately 1.0 foot lamberts (the slides consisted of transparencies with the alpha-numeric information appearing in white against a black background). The subject was seated 11" in front of the screen. Illumination level on the working surface for the subject was 1.1 foot candles.

The subject was seated and given a booklet containing instructions and answer charts. The experimenter read the instructions aloud and the subject was asked to read along with him silently. Several practice trials were then given to acquaint the subject with the experimental task. These trials were followed by the experimental presentations. The experimental task was as follows: The subject studied an uncoded chart in his booklet which represented hard copy "history". After one minute he closed the booklet, and was shown an updated "history" chart on the screen. In the updated chart, varying numbers of entries were different from the corresponding entries in the hard copy "history". After one minute, the updated chart was removed from the screen. The subject then reopened his booklet and was allowed one minute to locate and cross out the entries which had been updated.

FRIENDLY TACTICAL UNITS STATUS					
UNIT	ACTIVITY	EFF STRENGTH	TERRAIN	ARMOR STATUS	WEATHER
23	**LANDING**	77	FARMLAND	92	DAMP
72	REBUILDING	96	LOWLAND	85	**OVERCAST**
57	ASSEMBLING	87	RIVERS	91	SNOW
82	WITHDRAWING	**76**	MEADOWLAND	**82**	HUMID
34	FLANKING	80	MARSHLAND	76	RAIN
13	SUPPORTING	**71**	DESERT	96	HURRICANE
26	SURROUNDING	85	**FLATLAND**	**86**	SUNNY
99	SCREENING	90	SWAMP	87	WINDY
64	REGROUPING	78	**JUNGLE**	83	HAIL
41	PLANNING	83	LAKES	89	DRY
28	TRAINING	79	VALLEY	80	FREEZING
37	HOLDING	75	**CLIFFS**	78	**STORM**
18	PENETRATING	72	FOREST	**75**	HOT
53	**ASSAULTING**	94	HILLS	90	FOG
31	DEFENDING	**78**	MOUNTAINS	94	CLEAR

Figure 1. Example of Coded Updated Alpha-Numeric Information

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FRIENDLY TACTICAL UNITS STATUS					
UNIT	ACTIVITY	EFF STRENGTH	TERRAIN	ARMOR STATUS	WEATHER
23	SUPPLYING	77	FARMLAND	92	DAMP
72	REBUILDING	96	LOWLAND	85	SLEET
57	ASSEMBLING	87	RIVERS	91	SNOW
82	WITHDRAWING	81	MEADOWLAND	77	HUMID
34	FLANKING	80	MARSHLAND	76	RAIN
13	SUPPORTING	70	DESERT	96	HURRICANE
45	SURROUNDING	85	MUDDY	95	SUNNY
99	SCREENING	90	SWAMP	87	WINDY
64	REGROUPING	78	ROCKY	83	HAIL
24	PLANNING	83	LAKES	89	DRY
28	TRAINING	79	VALLEY	80	FREEZING
56	HOLDING	75	PLATEAU	78	COOL
18	PENETRATING	72	FOREST	70	HOT
53	ADVANCING	94	HILLS	90	FOG
31	DEFENDING	95	MOUNTAINS	94	CLEAR

Figure 2. Example of Hard-Copy History Answer Chart

SCORING

Accuracy and error scores were obtained for each trial. Two error scores were obtained, one for errors of omission and one for errors of commission. An error of omission was defined as the failure to locate an update. An error of commission was defined as the inaccurate location of an update. Percentages for accuracy and errors were obtained according to the following formulae:

1. $A = \frac{R}{R+O+C} \times 100$

2. $E_o = \frac{O}{R+O+C} \times 100$

3. $E_c = \frac{C}{R+O+C} \times 100$

where:

A = percent accuracy

E_o = percent omits

E_c = percent commits

R = number correct responses

O = number omits

C = number commits

VARIABLES

Independent Variables

1. Coded vs uncoded updated information

2. Total number of elements of information presented. An element was defined as that word or number which appeared in a given row and column of an alpha-numeric chart. The levels used in the study consisted of 36, 54, 72, and 90 elements presented.

3. Number of elements of information updated. The levels used were 4, 8, 12, and 16 updates.

Dependent Variables

1. Accuracy

2. Errors of omission; errors of commission

SUBJECTS

The subjects for this experiment were 30 enlisted men of above average intelligence as indicated by their scores for the General Technical Aptitude Area (110 or higher) of the Army Classification Battery. All subjects were required to have normal or corrected normal vision.

EXPERIMENTAL DESIGN

The subjects were randomly assigned to two groups of 15 men each, one performing with coded updates and the other with uncoded updates. Each group took all 16 treatment combinations of elements presented and elements updated. For purposes of administration, each group was divided into three subgroups of 5 each. Order of administration of trials was randomized for each subgroup. The design was planned with the possibility of combining the data for the coded and uncoded groups into one analysis if the variances proved to be homogeneous. The experimental layout is shown in Figure 3.

RESULTS

Analyses of variance of percentages were computed for accuracy, omits, and commits, and because of possible skewness of the data, for percentages transformed to log scores. Results of the analyses were essentially the same and showed all main effects to be significant at the .01 or .05 level --with one notable exception[1]--and indicated that interpretation could be based on the untransformed data. Summaries of the analyses and results of significance tests on untransformed data are shown in Tables 1, 2, and 3. Figures 4, 5, 6, and 7 show accuracy and error performance across levels of the independent variables. Summary tables of the mean percentages for the treatment combinations are shown in the appendix (Tables A-1 through A-6).

While the elements presented x elements updated interaction was significant for all the analyses, the "F's" were not large and the profiles of means for this interaction, with the exception of those for percent accuracy

[1] The effect on accuracy of number of uncoded elements updated was not significant with untransformed scores but was significant with transformed scores.

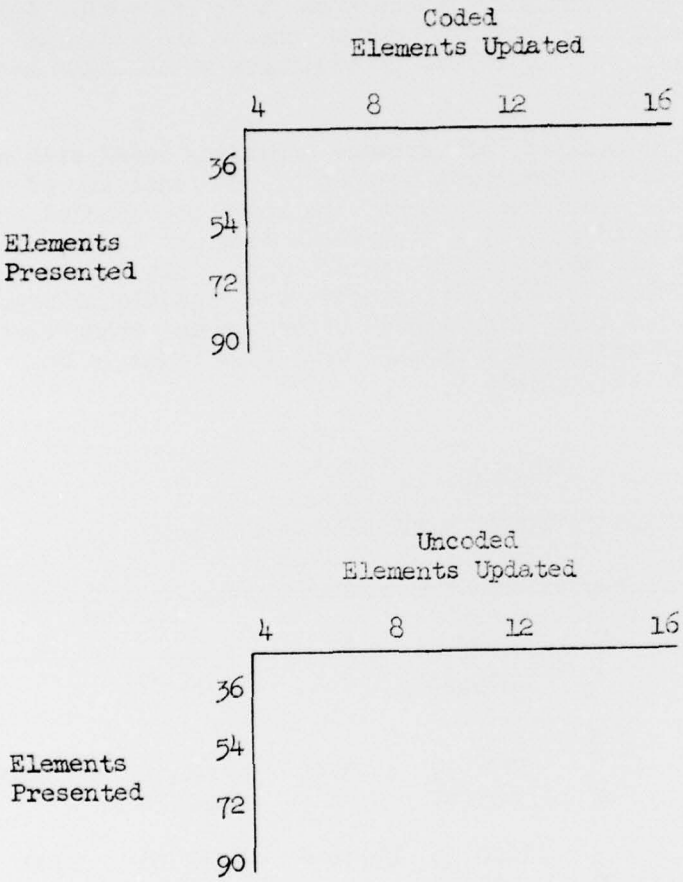

Figure 3. Experimental Layout of Study

with uncoded updates, did not reveal any meaningful trends. A closer examination of the means for percent accuracy with uncoded updates for this particular interaction showed somewhat puzzling results. Performance accuracy declined or remained stable for 36, 54, and 72 elements presented as the number of uncoded updates increased from 4 to 16. However, at the 90 level, performance accuracy actually increased from 3% to 16% (Table A-2)[2]. A re-examination of the hard copy "history" answer charts and stimulus materials did not reveal any scoring errors or artifacts which could have produced this unexpected result.

Since the results of an analysis of variance combining coded with uncoded displays were difficult to interpret because of heterogeneity of variance, differences between performance under the coded and uncoded conditions were tested for significance by a test which does not assume homogeneity of variance (Dixon and Massey, 1957, p. 123-124). The results of these tests are shown in Table 4. All differences were significant beyond the .05 level. With the same test, differences between mean percentages of omits and commits for coded and uncoded updates were also found to be significant beyond the .05 level (Table 5).

Table 1

SUMMARY OF ANALYSES OF VARIANCE OF PERCENT ACCURACY

Source of Variation	df	Coded MS	F	Uncoded MS	F
Between Subjects	14	2609.30		904.82	
Within Subjects	225				
Elements Presented (P)	3	7078.99	11.32**	10048.98	24.44**
Subjects (S) x P	42	625.44		411.16	
Elements Updated (U)	3	11610.15	13.46**	262.18	1.00
S x U	42	862.39		243.20	
P x U	9	1334.05	2.55*	785.78	4.01**
S x P x U	126	521.62		196.13	

* P< .05
** P< .01

[2] The effects of this reversal, combined with the nature of the distribution of percentages, produced the significant "F" for the main effect for transformed scores and showed performance accuracy actually to increase with increasing numbers of uncoded updates.

Table 2

SUMMARY OF ANALYSES OF VARIANCE OF PERCENTAGES OF OMITS

Source of Variation	df	Coded MS	F	Uncoded MS	F
Between Subjects	14	1116.61		3414.38	
Within Subjects	225				
Elements Presented (P)	3	4137.40	13.33**	4822.13	7.55**
Subjects (S) x P	42	310.87		638.98	
Elements Updated (U)	3	8894.47	30.85**	6751.98	14.32**
S x U	42	295.64		471.41	
P x U	9	834.01	3.51**	713.33	2.04*
S x P x U	126	237.49		349.51	

* P< .05
** P< .01

Table 3

SUMMARY OF ANALYSES OF VARIANCE OF PERCENTAGES OF COMMITS

Source of Variation	df	Coded MS	F	Uncoded MS	F
Between Subjects	14	517.11		2270.58	
Within Subjects	225				
Elements Presented (P)	3	769.66	3.60*	936.57	5.98**
Subjects (S) x P	42	221.55		156.73	
Elements Updated (U)	3	1509.68	6.03**	4103.42	19.83**
S x U	42	250.44		206.86	
P x U	9	328.33	1.97*	356.08	2.12*
S x P x U	126	166.93		168.18	

* P< .05
** P< .01

Table 4

DIFFERENCES BETWEEN PERCENTAGES OF CODED AND UNCODED UPDATES

	Coded	Uncoded	Significance Level
Accuracy	73	24	.01
Omits	16	58	.01
Commits	11	18	.05

Table 5

DIFFERENCES BETWEEN PERCENTAGES OF OMITS AND COMMITS

	Omits	Commits	Significance Level
Coded	16	11	.05
Uncoded	58	18	.01

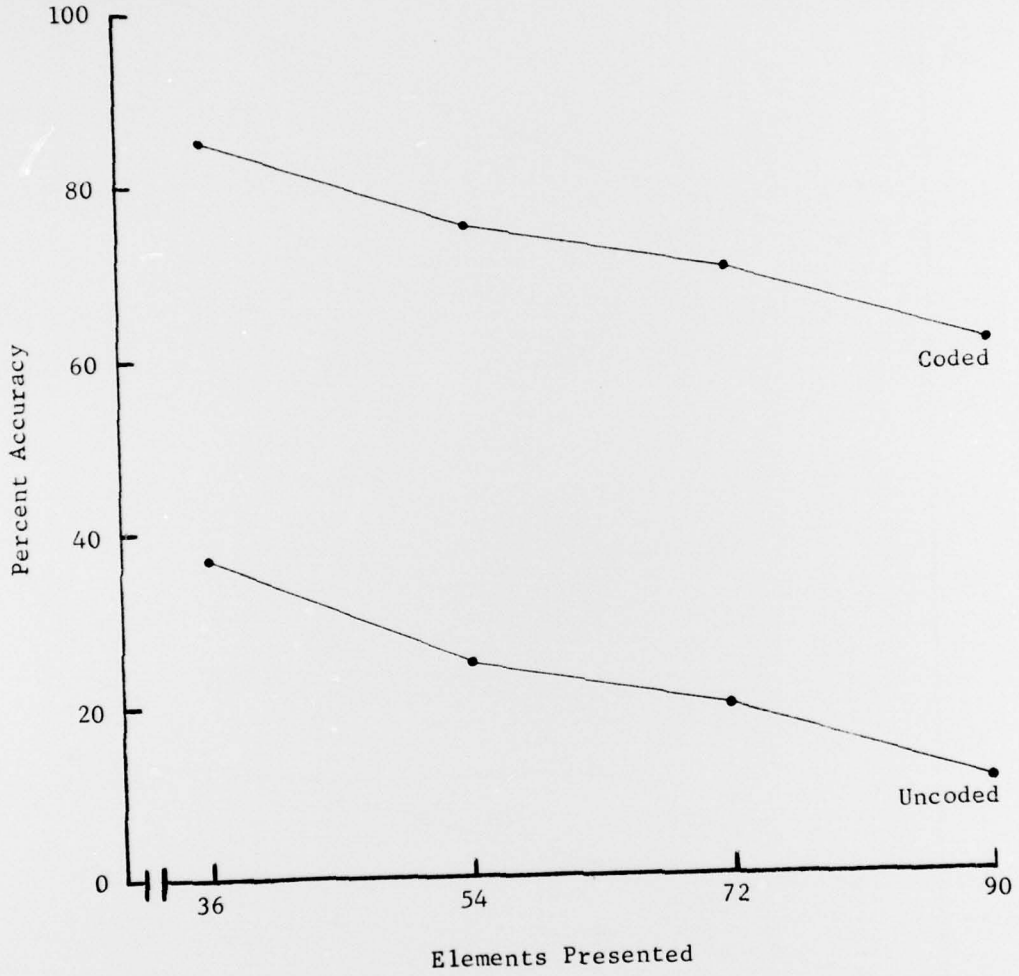

Figure 4. Percent Accuracy for Coded and Uncoded Updates at Each Level of Elements Presented.

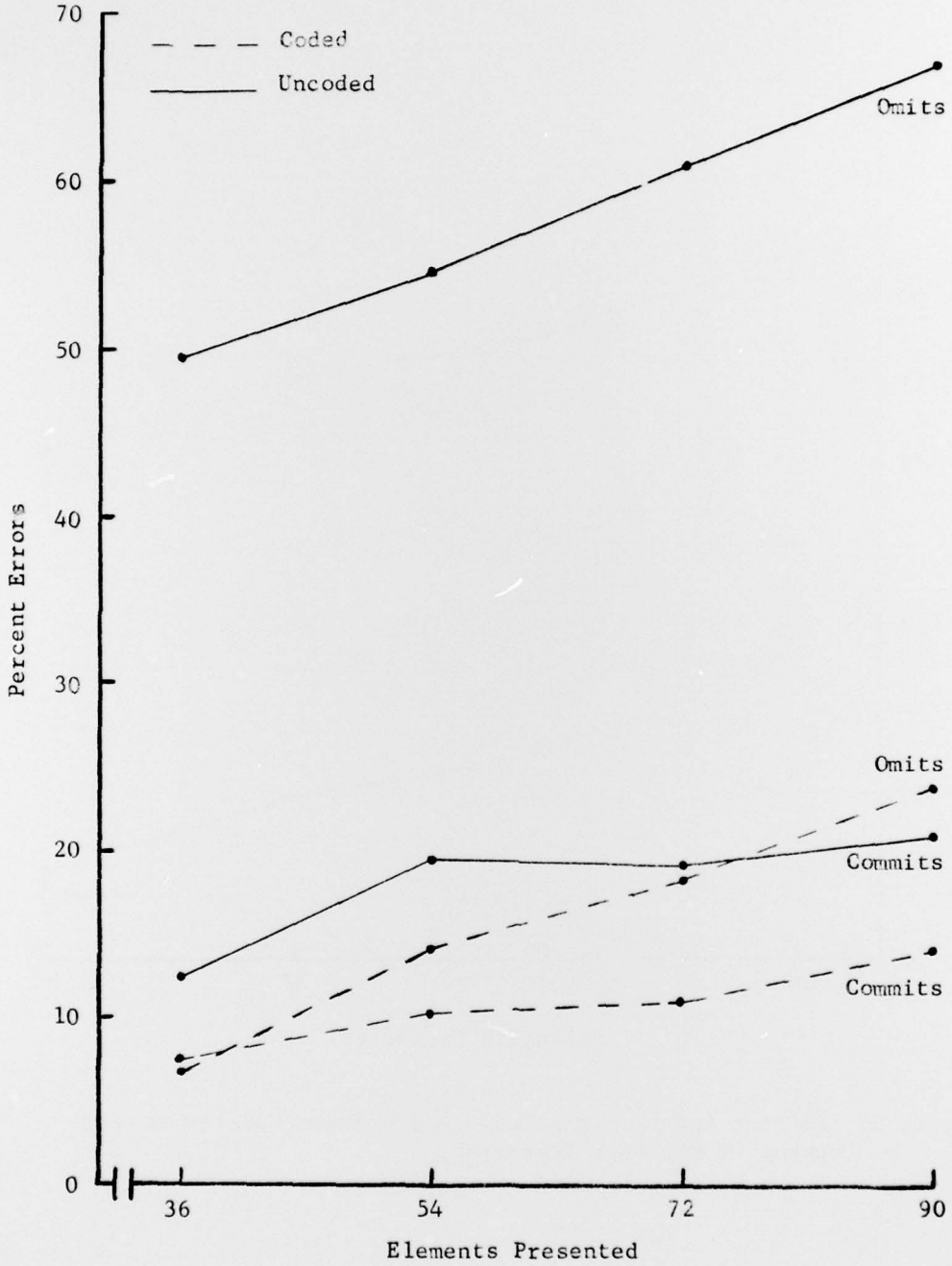

Figure 5. Percent Errors of Omission and Commission for Coded and Uncoded Updates at Each Level of Elements Presented.

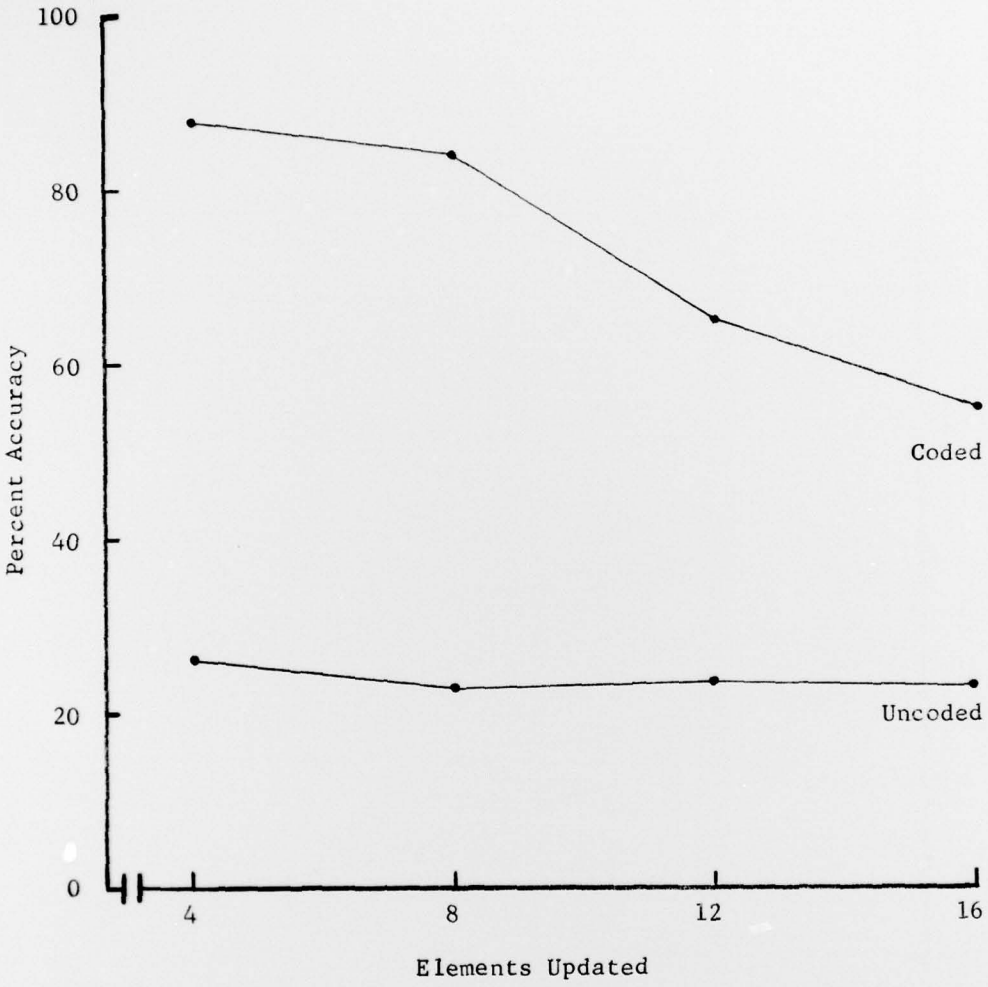

Figure 6. Percent Accuracy for Coded and Uncoded Updates at Each Level of Elements Updated.

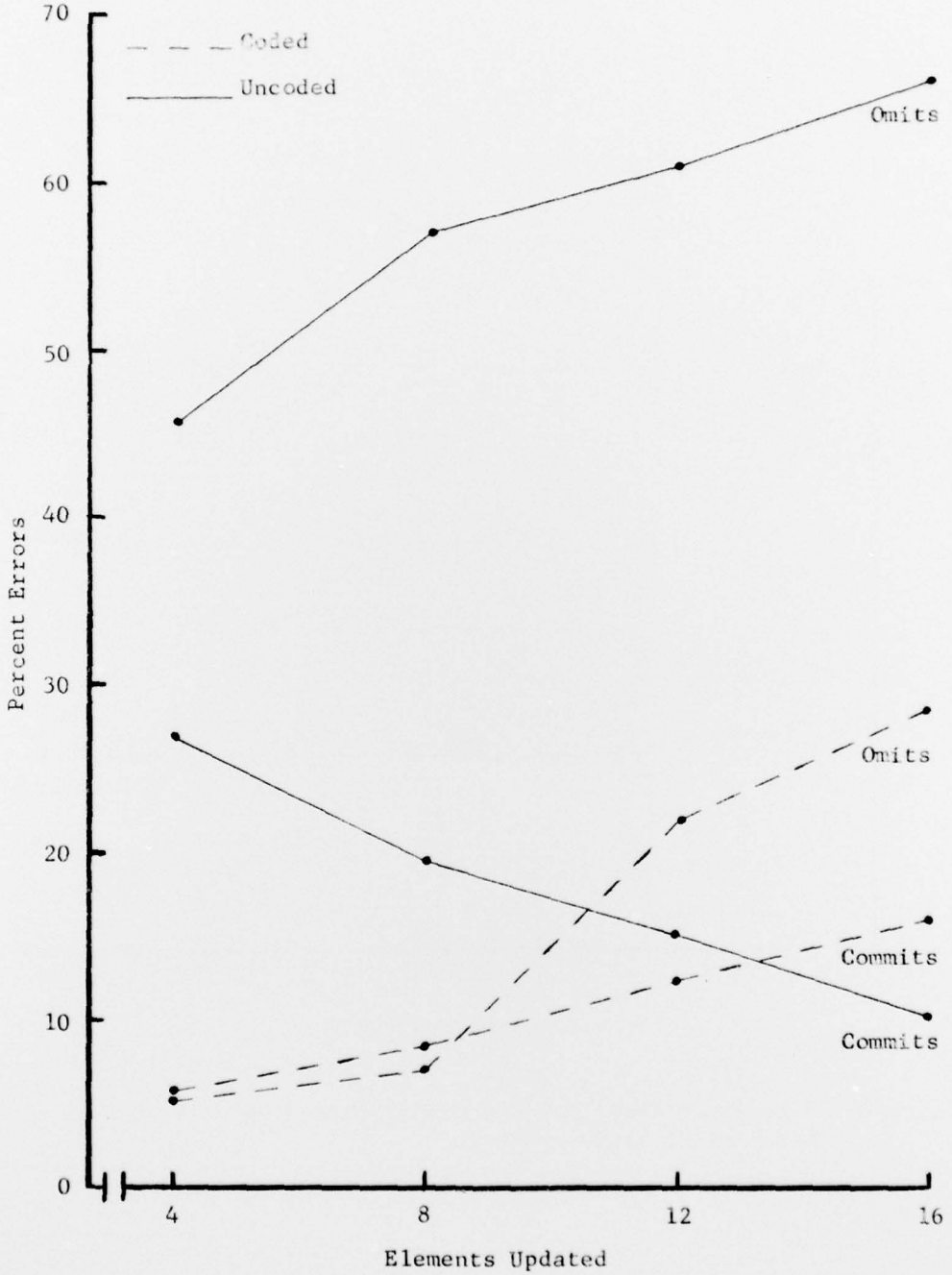

Figure 7. Percent Errors of Omission and Commission for Coded and Uncoded Updates at Each Level of Elements Updated.

The results of this study may be summarized as follows:

As the number of elements of information increased from 36 to 90:

1. Accuracy declined from 86% to 62% for coded updates and from 38% to 11% for uncoded updates (Figure 4).

2. Errors of omission increased from 7% to 24% for coded updates and from 49% to 67% for uncoded updates (Figure 5).

3. Errors of commission increased from 7% to 14% for coded updates and from 13% to 22% for uncoded updates (Figure 5).

As the number of elements of information updated increased from 4 to 16:

1. Accuracy declined from 88% to 56% for coded updates but remained approximately stable at 22% for uncoded updates (Figure 6). (This apparent stability of accuracy scores for uncoded updates may be somewhat suspect in view of the significant elements presented x elements updated interaction).

2. Errors of omission increased from 6% to 28% for coded updates and decreased from 27% to 11% for uncoded updates (Figure 7).

3. Errors of commission increased from 6% to 16% for coded updates and decreased from 27% to 11% for uncoded updates (Figure 7).

The following major differences were found as a function of the use of coded vs. uncoded updates respectively (Table 4):

1. Performance accuracy - 73% vs. 24%.

2. Errors of omission - 16% vs. 58%.

3. Errors of commission - 11% vs. 18%.

The percentages of omits were significantly larger than the percentages of commits for both coded and uncoded updates (Table 5).

Comparison of the results of the present study with those of a previous study on the assimilation of symbolic information (Ringel and Vicino, 1964) indicate the following:

1. Elements (or amount) of information presented affected performance accuracy similarly in both studies.

2. In both studies, errors of omission occurred with greater frequency than errors of commission.

IMPLICATIONS

The enhancement of performance accuracy as a function of coding updated information supports previous findings for the inclusion of a coding capability in proposed information processing systems (Hammer and Ringel, 1964). For information processing tasks similar to that used in the current study the particular coding technique used (size coding) is feasible from a standpoint of systems hardware capability, and may be as effective as other techniques which are more difficult and expensive to install.

The effects on performance of the number of elements presented and number of elements updated suggest that unless new techniques for presenting and assimilating alpha-numeric information are developed, limits may need to be set on amounts of information presented and updated on any one chart, graph, figure, overlay, etc. Such limits might create storage problems, particularly in those systems which carry the information on slides.

The preponderance of errors of omission over errors of commission obtained in the present study as well as in previous studies of both alpha-numeric and symbolic information (Hammer and Ringel, 1964, Ringel and Vicino, 1964) suggest a need to determine the respective and combined impact of these variables on information processing efficiency, particularly with respect to decision making in an operational setting.

In the case of uncoded updates, the profiles of means for the elements presented x elements updated interaction showed that when 90 elements were presented, performance accuracy actually increased as the number of elements updated was increased from 4 to 16. This unexpected finding might imply that at this level of difficulty, subjects used a different information processing technique. However, before a more definitive interpretation can be attached to these data, replication and further study are needed.

The data for 9 of the 15 subjects who worked with uncoded displays indicate that as the number of uncoded updates increased from 4 to 16, the combined proportions for accuracy and commits, which represent total overt responses, decreased while proportions of omits increased. Coupled with the apparent stability in performance accuracy (assuming that the significant elements presented x elements updated interaction did not mask a significant main effect), these findings may reflect an unrealistic increase in the perceived difficulty of the experimental task--an increase which may, in turn, relate to a reluctance on the part of subjects to risk making errors. A finding which may support this conjecture emerged from a study on assimilation of symbolic information (Andrews and Ringel, 1964) in which confidence was actually measured rather than inferred. The findings of both studies point out a need for research on the relationships among perceived difficulty, confidence, and performance, and the implication of these relationships for decision making.

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APPENDIX

Tables Showing Means of Accuracy and Error Scores
for all Treatment Combinations

Table A-1

PERCENT ACCURACY--CODED DISPLAYS

		Elements Updated 4	8	12	16	Mean
Elements Presented	36	97.30	95.97	79.48	73.87	86.90
	54	87.33	79.88	78.07	59.64	76.73
	72	87.67	90.30	48.09	55.25	71.77
	90	82.38	74.77	56.84	36.31	62.87
Mean		88.42	85.48	65.12	56.56	73.39

Table A-2

PERCENT ACCURACY--UNCODED DISPLAYS

		Elements Updated 4	8	12	16	Mean
Elements Presented	36	46.01	33.85	41.22	31.96	38.64
	54	26.20	25.42	27.87	25.65	26.79
	72	29.21	22.25	13.72	18.29	20.63
	90	3.96	11.41	14.07	16.54	11.01
Mean		26.08	23.97	24.71	23.35	24.77

Table A-3

PERCENT ERRORS OF OMISSION--CODED DISPLAYS

		Elements Updated 4	8	12	16	Mean
Elements Presented	36	1.33	2.48	11.44	13.14	7.85
	54	6.78	10.97	15.27	26.64	14.17
	72	5.33	5.48	34.45	30.16	18.36
	90	10.01	13.65	29.80	44.30	24.94
Mean		6.61	7.15	22.24	28.31	16.83

Table A-4

PERCENT ERRORS OF OMISSION--UNCODED DISPLAYS

		Elements Updated 4	8	12	16	Mean
Elements Presented	36	34.53	52.66	53.19	60.60	50.48
	54	48.01	51.81	57.73	63.06	55.86
	72	38.61	63.89	70.49	74.77	61.93
	90	68.56	64.39	65.96	72.54	67.10
Mean		47.68	57.44	61.10	66.99	58.07

Table A-5

PERCENT ERRORS OF COMMISSION--CODED DISPLAYS

		Elements Updated				
		4	8	12	16	Mean
Elements Presented	36	1.30	4.55	10.07	14.99	7.23
	54	7.89	11.20	7.64	16.73	10.12
	72	8.00	5.22	18.44	15.58	12.56
	90	8.59	14.57	15.33	20.19	14.17
Mean		6.95	8.39	13.62	16.12	11.77

Table A-6

PERCENT ERRORS OF COMMISSION--UNCODED DISPLAYS

		Elements Updated				
		4	8	12	16	Mean
Elements Presented	36	21.45	16.49	5.30	10.45	13.67
	54	26.79	24.77	16.40	12.27	20.56
	72	33.18	15.06	18.77	8.90	19.48
	90	30.48	24.20	21.98	13.90	22.89
Mean		27.23	20.63	15.11	11.63	18.15